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Vladislav et al.

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(54) **PARAMETER INFERENCE METHOD, CALCULATION APPARATUS, AND SYSTEM BASED ON LATENT DIRICHLET ALLOCATION MODEL**

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G06N 5/04	(2006.01)
G06F 17/30	(2006.01)
G06K 9/62	(2006.01)

(52) **U.S. Cl.**

CPC ***G06N 5/048*** (2013.01); ***G06F 17/30011*** (2013.01); ***G06K 9/6218*** (2013.01)

(58) **Field of Classification Search**

CPC G06N 5/043
USPC 706/52
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2007/0118498	A1	5/2007	Song et al.
2008/0319974	A1	12/2008	Ma et al.
2009/0089036	A1	4/2009	Shi et al.

FOREIGN PATENT DOCUMENTS

CN	101399708	A	4/2009
CN	101587493	A	11/2009
CN	101710333	A	5/2010

OTHER PUBLICATIONS

Newman et al ("Distributed Inference for Latent Dirichlet Allocation" 2007).*

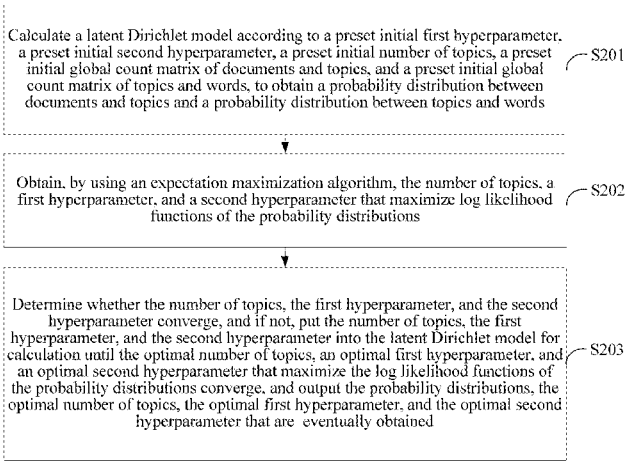
(Continued)

Primary Examiner — Lut Wong
(74) *Attorney, Agent, or Firm* — Conley Rose, P.C.; Grant Rodolph; Nicholas K. Beaulieu

(57) **ABSTRACT**

A parameter inference method to solve a problem that precision of a Latent Dirichlet Allocation model is poor is provided. The method includes: calculating a Latent Dirichlet Allocation model according to a preset initial first hyperparameter, a preset initial second hyperparameter, a preset initial number of topics, a preset initial count matrix of documents and topics, and a preset initial count matrix of topics and words to obtain probability distributions; obtaining the number of topics, a first hyperparameter, and a second hyperparameter that maximize log likelihood functions of the probability distributions; and determining whether the number of topics, the first hyperparameter, and the second hyperparameter converge, and if not, putting the number of topics, the first hyperparameter, and the second hyperparameter into the Latent Dirichlet Allocation model until the optimal number of topics, an optimal first hyperparameter, and an optimal second hyperparameter that maximize the log likelihood functions of the probability distributions.

5 Claims, 7 Drawing Sheets



(56) **References Cited**

OTHER PUBLICATIONS

Asuncion et al ("Asynchronous Distributed Estimation of Topic Models for Document Analysis" Mar. 18, 2010).*

Foreign Communication From a Counterpart Application, PCT Application No. PCT/CN2011/077097, English Translation of Chinese Search Report dated Apr. 26, 2012, 2 pages.

Foreign Communication From a Counterpart Application, PCT Application No. PCT/CN2011/077097, English Translation of Chinese Written Opinion dated Apr. 26, 2012, 10 pages.

Partial English Translation and Abstract of Chinese Patent Application No. CN101710333, Aug. 13, 2013, 13 pages.

Wang, Y., et al., "PLDA: Parallel Latent Dirichlet Allocation for Large-Scale Applications," AAIM '09 Proceedings of the 5th International Conference on Algorithmic Aspects in Information and Management, 2009, 14 pages.

Jaun, C., et al., "A Method of Adaptively Selecting Best LDA Model Based on Density," vol. 31, No. 10, China Academic Journal Electronic Publishing House, Chinese Journal of Computers, Oct. 31, 2008, 8 pages.

* cited by examiner

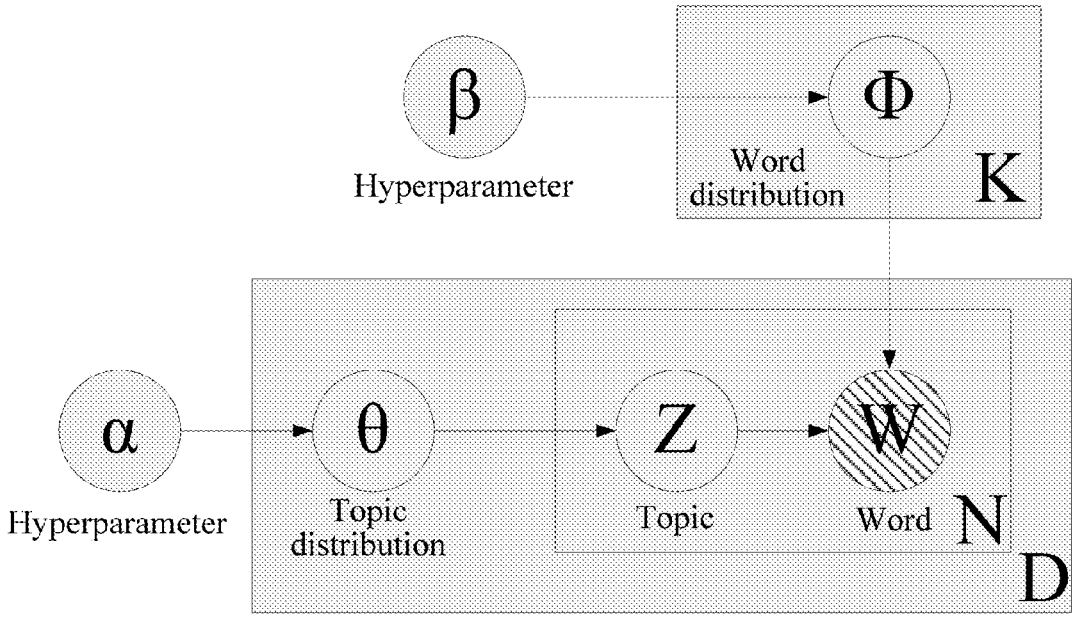

β
Hyperparameter
Φ
Word distribution
K
α
Hyperparameter
θ
Topic distribution
Z
Topic
W
Word
N
D

FIG. 1

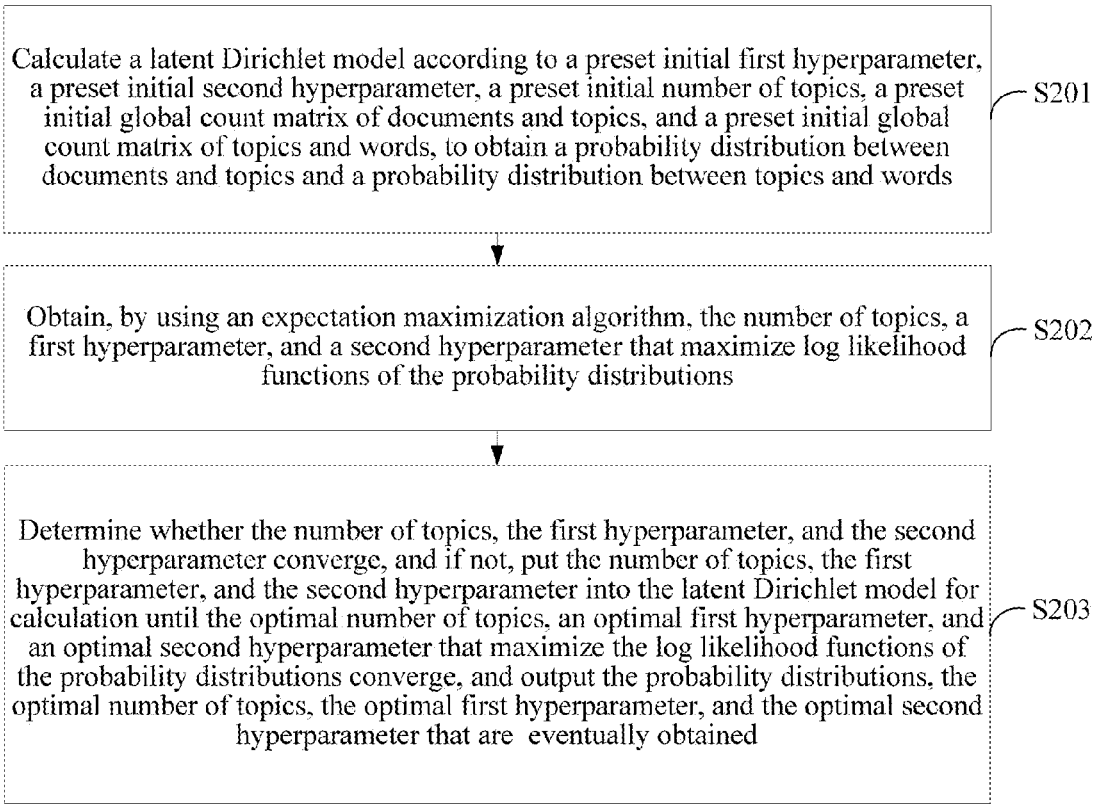

Calculate a latent Dirichlet model according to a preset initial first hyperparameter, a preset initial second hyperparameter, a preset initial number of topics, a preset initial global count matrix of documents and topics, and a preset initial global count matrix of topics and words, to obtain a probability distribution between documents and topics and a probability distribution between topics and words
S201
Obtain, by using an expectation maximization algorithm, the number of topics, a first hyperparameter, and a second hyperparameter that maximize log likelihood functions of the probability distributions
S202
Determine whether the number of topics, the first hyperparameter, and the second hyperparameter converge, and if not, put the number of topics, the first hyperparameter, and the second hyperparameter into the latent Dirichlet model for calculation until the optimal number of topics, an optimal first hyperparameter, and an optimal second hyperparameter that maximize the log likelihood functions of the probability distributions converge, and output the probability distributions, the optimal number of topics, the optimal first hyperparameter, and the optimal second hyperparameter that are eventually obtained
S203

FIG. 2

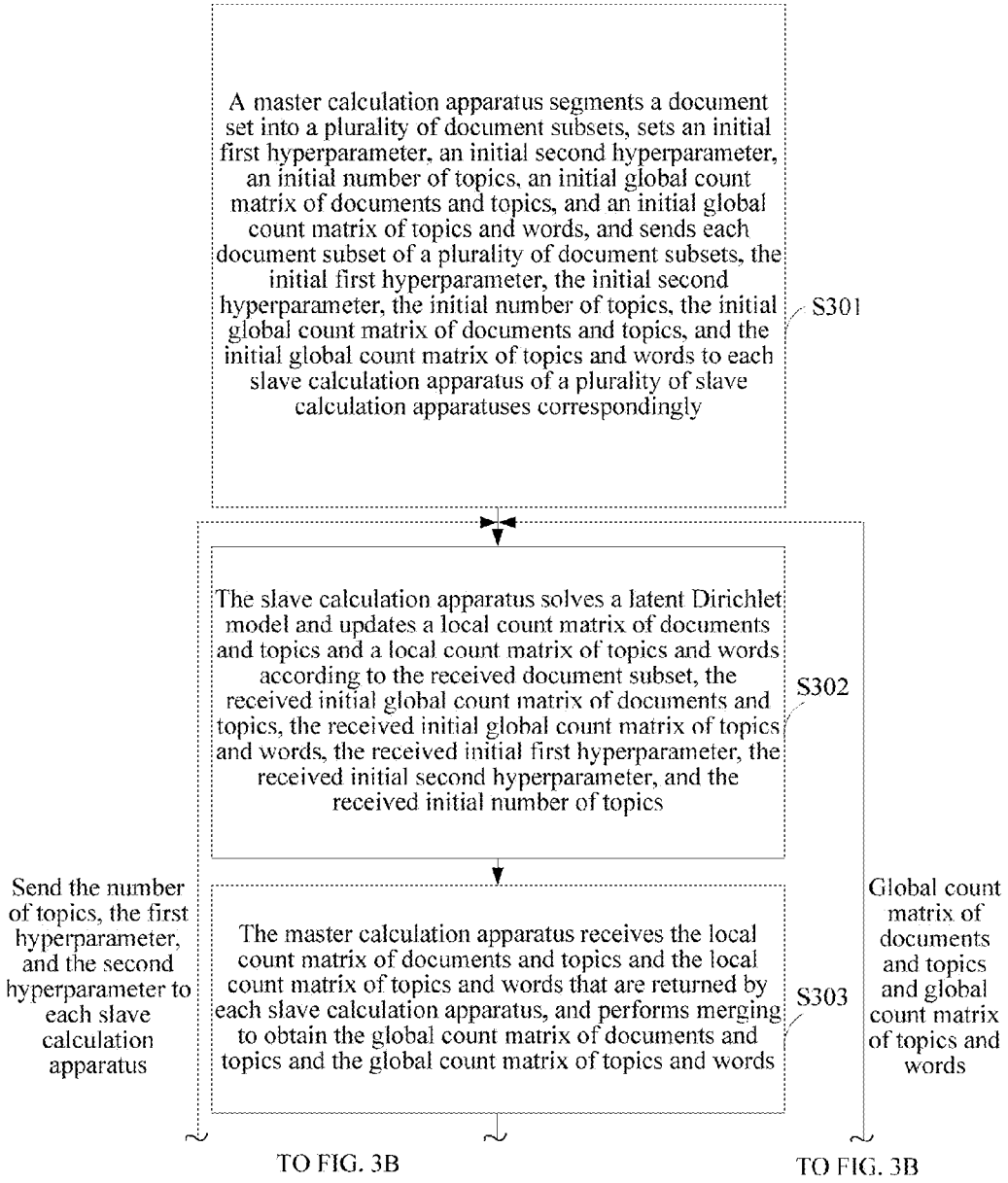

A master calculation apparatus segments a document set into a plurality of document subsets, sets an initial first hyperparameter, an initial second hyperparameter, an initial number of topics, an initial global count matrix of documents and topics, and an initial global count matrix of topics and words, and sends each document subset of a plurality of document subsets, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words to each slave calculation apparatus of a plurality of slave calculation apparatuses correspondingly
S301
The slave calculation apparatus solves a latent Dirichlet model and updates a local count matrix of documents and topics and a local count matrix of topics and words according to the received document subset, the received initial global count matrix of documents and topics, the received initial global count matrix of topics and words, the received initial first hyperparameter, the received initial second hyperparameter, and the received initial number of topics
S302
Send the number of topics, the first hyperparameter, and the second hyperparameter to each slave calculation apparatus
The master calculation apparatus receives the local count matrix of documents and topics and the local count matrix of topics and words that are returned by each slave calculation apparatus, and performs merging to obtain the global count matrix of documents and topics and the global count matrix of topics and words
S303
Global count matrix of documents and topics and global count matrix of topics and words
TO FIG. 3B
TO FIG. 3B

FIG. 3A

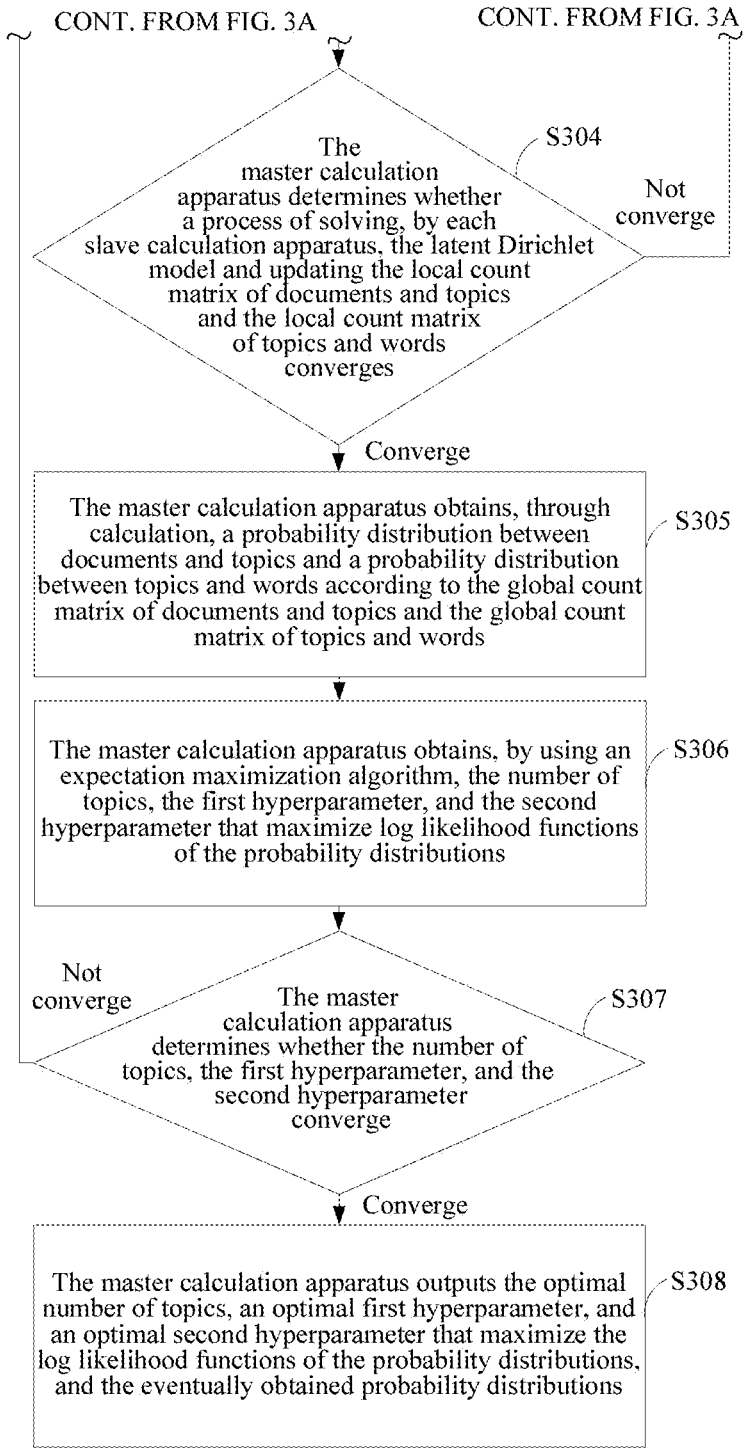

CONT. FROM FIG. 3A
CONT. FROM FIG. 3A
The master calculation apparatus determines whether a process of solving, by each slave calculation apparatus, the latent Dirichlet model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges
S304
Not converge
Converge
The master calculation apparatus obtains, through calculation, a probability distribution between documents and topics and a probability distribution between topics and words according to the global count matrix of documents and topics and the global count matrix of topics and words
S305
The master calculation apparatus obtains, by using an expectation maximization algorithm, the number of topics, the first hyperparameter, and the second hyperparameter that maximize log likelihood functions of the probability distributions
S306
Not converge
The master calculation apparatus determines whether the number of topics, the first hyperparameter, and the second hyperparameter converge
S307
Converge
The master calculation apparatus outputs the optimal number of topics, an optimal first hyperparameter, and an optimal second hyperparameter that maximize the log likelihood functions of the probability distributions, and the eventually obtained probability distributions
S308

FIG. 3B

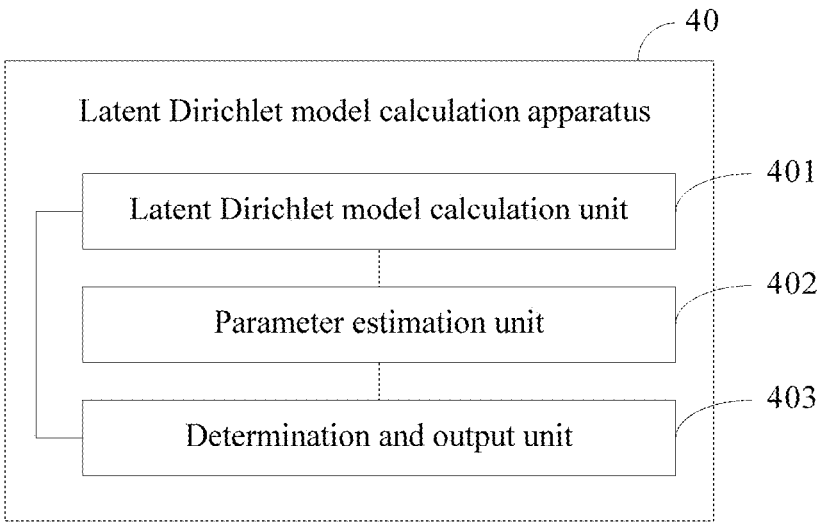

40
Latent Dirichlet model calculation apparatus
Latent Dirichlet model calculation unit
401
Parameter estimation unit
402
Determination and output unit
403

FIG. 4

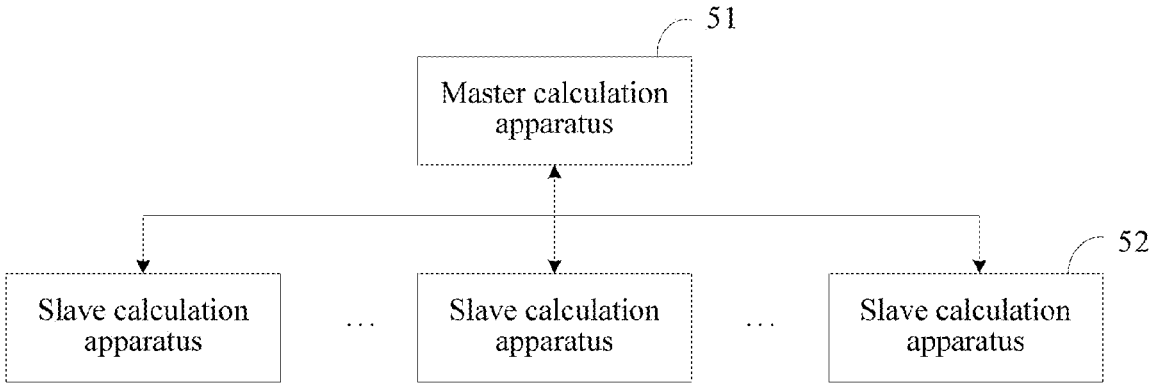

51
Master calculation apparatus
52
Slave calculation apparatus
...
Slave calculation apparatus
...
Slave calculation apparatus

FIG. 5

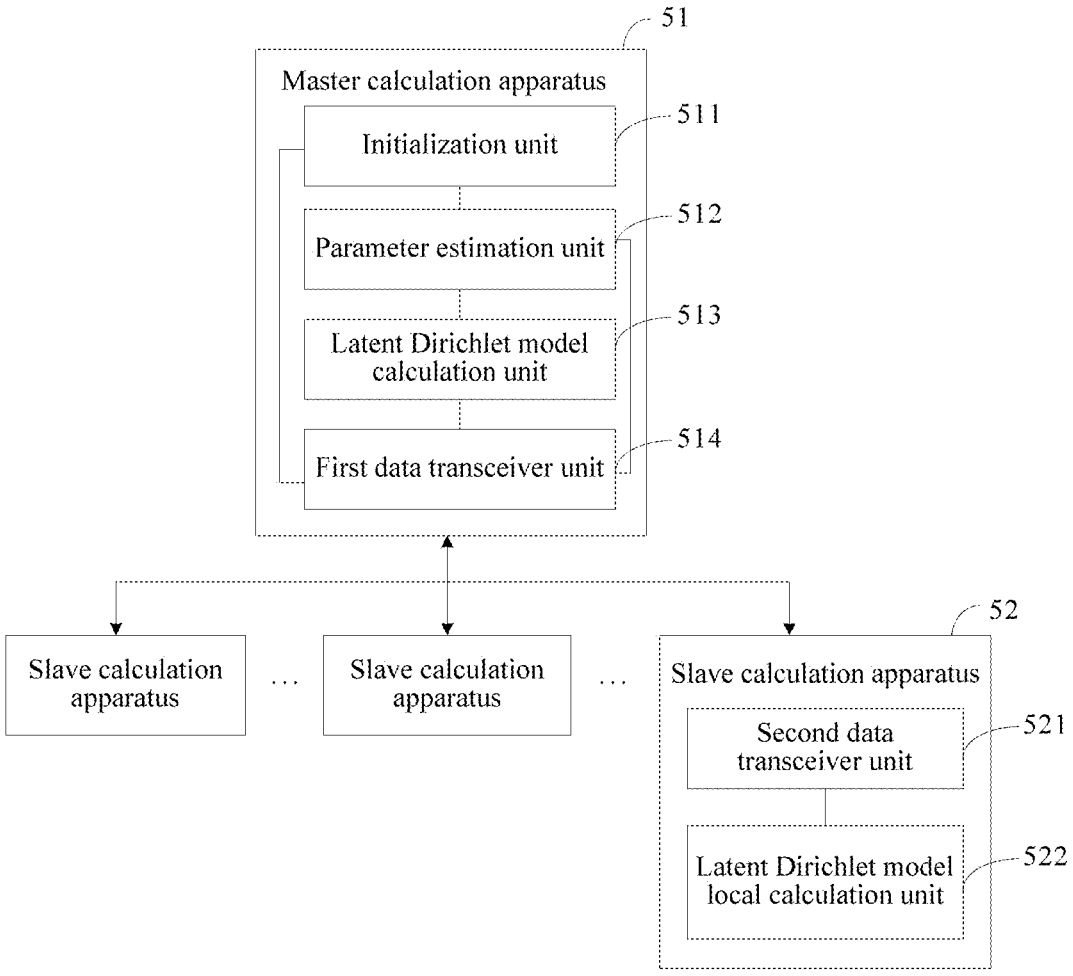

51
Master calculation apparatus
511
Initialization unit
512
Parameter estimation unit
513
Latent Dirichlet model calculation unit
514
First data transceiver unit
Slave calculation apparatus
...
Slave calculation apparatus
...
52
Slave calculation apparatus
521
Second data transceiver unit
522
Latent Dirichlet model local calculation unit

FIG. 6

PARAMETER INFERENCE METHOD, CALCULATION APPARATUS, AND SYSTEM BASED ON LATENT DIRICHLET ALLOCATION MODEL

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of International Application No. PCT/CN2011/077097, filed on Jul. 13, 2011, which is hereby incorporated by reference in its entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable.

REFERENCE TO A MICROFICHE APPENDIX

Not applicable.

TECHNICAL FIELD

The present invention relates to the field of information retrieval, and in particular, to a parameter inference method, calculation apparatus, and system based on a Latent Dirichlet Allocation model.

BACKGROUND

With the rapid development of the Internet, information on the Internet increases exponentially. For such a huge number of information resources, how to obtain required information effectively and quickly becomes more and more important for people. To improve quality and efficiency of information retrieval of users, many powerful information retrieval tools such as search engines appear one after another. Search engines bring great convenience to people; however, it turns out that search technologies in which a keyword is used as a basic indexing unit have many defects. In one aspect, too many results are returned for any keyword submitted by a user, among which only a small part of information is what the user actually needs, causing that the user has to spend a considerable amount of time in manually filtering these results; in another aspect, many documents related to a search topic may not include a keyword input by the user, resulting in that these documents cannot be found by a search engine.

Performing automatic classification on information is an effective approach to solve the foregoing problem, which can significantly solve problems of heterogeneous and disorderly information on the Internet, so as to narrow a search range, increase a retrieval speed, and improve a query result. Because currently, most information on the Internet appears in a form of a document, such as electronic mail (e-mail), electronic magazine, technical report, news, and online library, methods and technologies of document classification become the most important research focuses in the field of information retrieval.

A main task of document classification is to automatically determine an associated category according to document content. Currently, statistics-based and machine learning-based document classification methods are the most used by people. A common model of Bayesian classification, one of the statistics-based document classification methods, is a Latent Dirichlet Allocation model.

The Latent Dirichlet Allocation model is a probability generation model and can be used to identify latent topic information in a large-sized document set or corpus. The Latent Dirichlet Allocation model uses a bag-of-words method, in which each document is regarded as a word frequency vector, so that document information is changed into digital information that can be easily modeled. Each document represents a probability distribution formed by some topics, and each topic represents a probability distribution formed by many words.

For each document in a corpus, the Latent Dirichlet Allocation defines the following generation process:

(1) for each document, extracting a topic from a topic distribution;

(2) extracting a word in a word distribution corresponding to the extracted topic; and

(3) repeating the process until every word in the document is traversed.

Referring to FIG. **1**, in a more formal manner, each document in a corpus corresponds to one multinomial distribution of K topics (K is given in advance by using repeated experiments or another method), and the multinomial distribution is marked as θ. Each topic corresponds to one multinomial distribution of V words in a vocabulary, and the multinomial distribution is marked as Φ. θ and Φ each have one Dirichlet prior distribution with hyperparameters α and β. For each word in one document d, a topic Z is extracted from the multinomial distribution θ corresponding to the document, and then a word ω is extracted from the multinomial distribution Φ corresponding to the topic Z. A document D is generated by repeating the process Nd times, where Nd is the total number of words of the document D. In FIG. **1**, a shaded circle represents an observable variable, an unshaded circle represents a latent variable, an arrow represents a condition dependency between two variables, and a box represents repeated sampling, where the number of times of repetition is shown at the lower right corner of the box.

The Latent Dirichlet Allocation model has two parameters that need to be inferred. One is a "document-topic" distribution θ, and the other is a distribution Φ of K "topic-words". By learning these two parameters, a topic in which a document author is interested and proportions of topics covered in each document can be known.

Through actual calculation, it can be found that, for large-sized document data, although the Latent Dirichlet Allocation model can simulate a correlation between a topic and a word in a document, it is required to manually specify the optimal number of topics K in advance according to experience, and the input number of topics K has a significant impact on precision of a model to be solved. Therefore, how to choose the optimal number of topics K is still a difficult problem.

SUMMARY

Embodiments of the present invention provide a parameter inference method, calculation apparatus, and system based on a Latent Dirichlet Allocation model, so as to solve a problem in which solution precision of a Latent Dirichlet Allocation model is poor because the manually input number of topics is inaccurate.

In order to achieve the foregoing objectives, the embodiments of the present invention adopt the following technical solutions.

In one aspect, a parameter inference method based on a Latent Dirichlet Allocation model is provided and includes: calculating a Latent Dirichlet Allocation model according to a preset initial first hyperparameter, a preset initial second hyperparameter, a preset initial number of topics, a preset initial global count matrix of documents and topics, and a

preset initial global count matrix of topics and words, to obtain a probability distribution between documents and topics and a probability distribution between topics and words; obtaining, by using an expectation maximization algorithm, a first hyperparameter, a second hyperparameter, and the number of topics that maximize log likelihood functions of the probability distributions; and determining whether the first hyperparameter, the second hyperparameter, and the number of topics converge, and if not, putting the first hyperparameter, the second hyperparameter, and the number of topics into the Latent Dirichlet Allocation model for calculation until an optimal first hyperparameter, an optimal second hyperparameter, and the optimal number of topics that maximize the log likelihood functions of the probability distributions converge, and outputting the probability distributions, the optimal first hyperparameter, the optimal second hyperparameter, and the optimal number of topics that are eventually obtained.

In one aspect, a parameter inference calculation apparatus based on a Latent Dirichlet Allocation model is provided and includes: a Latent Dirichlet Allocation model calculation unit configured to calculate a Latent Dirichlet Allocation model according to a preset initial first hyperparameter, a preset initial second hyperparameter, a preset initial number of topics, a preset initial global count matrix of documents and topics, and a preset initial global count matrix of topics and words, to obtain a probability distribution between documents and topics and a probability distribution between topics and words; a parameter estimation unit configured to obtain, by using an expectation maximization algorithm, a first hyperparameter, a second hyperparameter, and the number of topics that maximize log likelihood functions of the probability distributions; and a determination and output unit configured to determine whether the first hyperparameter, the second hyperparameter, and the number of topics converge, and if not, put the first hyperparameter, the second hyperparameter, and the number of topics into the Latent Dirichlet Allocation model for calculation until an optimal first hyperparameter, an optimal second hyperparameter, and the optimal number of topics that maximize the log likelihood functions of the probability distributions converge, and output the probability distributions, the optimal first hyperparameter, the optimal second hyperparameter, and the optimal number of topics that are eventually obtained.

In one aspect, a parameter inference calculation system based on a Latent Dirichlet Allocation model is provided and includes: a master calculation apparatus configured to segment a document set into a plurality of document subsets; set an initial first hyperparameter, an initial second hyperparameter, an initial number of topics, an initial global count matrix of documents and topics, and an initial global count matrix of topics and words; send each document subset of a plurality of document subsets, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words to each slave calculation apparatus of a plurality of slave calculation apparatuses correspondingly; receive a local count matrix of documents and topics and a local count matrix of topics and words that are returned by each slave calculation apparatus, and perform merging to obtain a global count matrix of documents and topics and a global count matrix of topics and words; determine whether a process of solving, by each slave calculation apparatus, the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges; and if not, send the global count matrix of documents and topics and the global count matrix of topics and words to each slave calculation apparatus correspondingly for calculation, and continue to update the local count matrix of documents and topics and the local count matrix of topics and words until the process of calculating the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges, and output the global count matrix of documents and topics and global count matrix of topics and words that are eventually obtained; obtain, through calculation, a probability distribution between documents and topics and a probability distribution between topics and words according to the global count matrix of documents and topics and the global count matrix of topics and words; obtain, by using an expectation maximization algorithm, a first hyperparameter, a second hyperparameter, and the number of topics that maximize log likelihood functions of the probability distributions; determine whether the first hyperparameter, the second hyperparameter, and the number of topics converge, and if not, send the first hyperparameter, the second hyperparameter, and the number of topics to each slave calculation apparatus until an optimal first hyperparameter, an optimal second hyperparameter, and the optimal number of topics that maximize the log likelihood functions of the probability distributions converge, and output the probability distributions, the optimal first hyperparameter, the optimal second hyperparameter, and the optimal number of topics that are eventually obtained; and a plurality of slave calculation apparatuses configured to receive the document subset, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words that are sent by the master calculation apparatus, calculate the Latent Dirichlet Allocation model, update the local count matrix of documents and topics and the local count matrix of topics and words, and return the local count matrix of documents and topics and the local count matrix of topics and words to the master calculation apparatus; receive the global count matrix of documents and topics and the global count matrix of topics and words that are sent by the master calculation apparatus and put them into the Latent Dirichlet Allocation model for local calculation; receive the first hyperparameter, the second hyperparameter, the number of topics and put them into the Latent Dirichlet Allocation model for local calculation.

In the parameter inference method, calculation apparatus, and system based on a Latent Dirichlet Allocation model according to the embodiments of the present invention, the number of topics, a first hyperparameter, and a second hyperparameter that maximize log likelihood functions of a probability distribution between documents and topics and a probability distribution between topics and words can be obtained through adaptively solving by using an expectation maximization algorithm, thereby avoiding the number of topics manually specified in advance according to experience and improving precision of a calculation result of a Latent Dirichlet Allocation model.

BRIEF DESCRIPTION OF THE DRAWINGS

To describe the technical solutions in the embodiments of the present invention or in the prior art more clearly, the following briefly introduces accompanying drawings required for describing the embodiments or the prior art. The accompanying drawings in the following description show merely some embodiments of the present invention, and per-

sons of ordinary skill in the art may further obtain other drawings according to these accompanying drawings without creative efforts.

FIG. **1** is a graphical model representation diagram of a Latent Dirichlet Allocation model;

FIG. **2** is a flow chart of a parameter inference method based on a Latent Dirichlet Allocation model according to the present invention;

FIG. **3**A and FIG. **3**B is a flow chart of a parameter inference method based on a Latent Dirichlet Allocation model according to another embodiment of the present invention;

FIG. **4** is a schematic structural diagram of a parameter inference calculation apparatus based on a Latent Dirichlet Allocation model according to an embodiment of the present invention;

FIG. **5** is a schematic structural diagram of a parameter inference calculation system based on a Latent Dirichlet Allocation model according to an embodiment of the present invention; and

FIG. **6** is a schematic structural diagram of a parameter inference calculation system based on a Latent Dirichlet Allocation model according to another embodiment of the present invention.

DETAILED DESCRIPTION

The following clearly describes the technical solutions in the embodiments of the present invention with reference to the accompanying drawings in the embodiments of the present invention. The embodiments to be described are merely a part rather than all of the embodiments of the present invention. All other embodiments obtained by persons of ordinary skill in the art based on the embodiment of the present invention without creative efforts shall fall within the protection scope of the present invention.

In the following embodiments, "a first hyperparameter" refers to a hyperparameter of a "document-topic" distribution, and "a second hyperparameter" refers to a hyperparameter of a distribution of "topic-words" of "the number of topics". By learning the "document-topic" distribution and the "topic-word" distribution in a Latent Dirichlet Allocation result, a topic in which a document author is interested and proportions of topics covered in each document can be known.

As shown in FIG. **2**, a parameter inference method based on a Latent Dirichlet Allocation model according to an embodiment of the present invention includes the following steps.

S**201**: Calculate a Latent Dirichlet Allocation model according to a preset initial first hyperparameter, a preset initial second hyperparameter, a preset initial number of topics, a preset initial global count matrix of documents and topics, and a preset initial global count matrix of topics and words, to obtain a probability distribution between documents and topics and a probability distribution between topics and words.

S**202**: Obtain, by using an expectation maximization algorithm, the number of topics, a first hyperparameter, and a second hyperparameter that maximize log likelihood functions of the probability distributions.

S**203**: Determine whether the number of topics, the first hyperparameter, and the second hyperparameter converge, and if not, put the number of topics, the first hyperparameter, and the second hyperparameter into the Latent Dirichlet Allocation model for calculation until an optimal number of topics, an optimal first hyperparameter, and an optimal second hyperparameter that maximizes the log likelihood functions of the probability distributions converge, and output the probability distributions, the optimal number of topics, the optimal first hyperparameter, and the optimal second hyperparameter that are eventually obtained.

In the parameter inference method based on a Latent Dirichlet Allocation model according to the embodiment of the present invention, the number of topics, a first hyperparameter, and a second hyperparameter that maximize log likelihood functions of a probability distribution between documents and topics and a probability distribution between topics and words can be obtained through adaptively solving by using an expectation maximization algorithm, thereby avoiding the number of topics manually specified in advance according to experience and improving precision of a calculation result of a Latent Dirichlet Allocation model.

As shown in FIG. **3**A and FIG. **3**B, another parameter inference method based on a Latent Dirichlet Allocation model according to another embodiment of the present invention includes:

S**301**: A master calculation apparatus segments a document set into a plurality of document subsets, sets an initial first hyperparameter, an initial second hyperparameter, an initial number of topics, an initial global count matrix of documents and topics, and an initial global count matrix of topics and words, and sends each document subset of a plurality of document subsets, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words to each slave calculation apparatus of a plurality of slave calculation apparatuses correspondingly.

S**302**: The slave calculation apparatus solves a Latent Dirichlet Allocation model and updates a local count matrix of documents and topics and a local count matrix of topics and words according to the received document subset, the received initial global count matrix of documents and topics, the received initial global count matrix of topics and words, the received initial first hyperparameter, the received initial second hyperparameter, and the received initial number of topics.

S**303**: The master calculation apparatus receives the local count matrix of documents and topics and the local count matrix of topics and words that are returned by each slave calculation apparatus, and performs merging to obtain a global count matrix of documents and topics and a global count matrix of topics and words.

S**304**: The master calculation apparatus determines whether a process of solving, by each slave calculation apparatus, the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges, and if not, send the global count matrix of documents and topics and the global count matrix of topics and words to each slave calculation apparatus, and perform step S**302**. If yes, perform step S**305**.

S**305**: The master calculation apparatus obtains, through calculation, a probability distribution between documents and topics and a probability distribution between topics and words according to the global count matrix of documents and topics and the global count matrix of topics and words.

S**306**: The master calculation apparatus obtains, by using an expectation maximization algorithm, the number of topics, a first hyperparameter, and a second hyperparameter that maximize log likelihood functions of the probability distributions.

S**307**: The master calculation apparatus determines whether the number of topics, the first hyperparameter, and

the second hyperparameter converge. If not, perform step S**302**. In this case, the master calculation apparatus sends the number of topics, the first hyperparameter, and the second hyperparameter to each slave calculation apparatus, so that each slave calculation apparatus puts the number of topics, the first hyperparameter, and the second hyperparameter into the Latent Dirichlet Allocation model for local calculation. If yes, perform step S**308**.

S**308**: The master calculation apparatus outputs an optimal number of topics, an optimal first hyperparameter, and an optimal second hyperparameter that maximize the log likelihood functions of the probability distributions, and the eventually obtained probability distributions.

It should be noted that, in S**302**, the solving the Dirichlet model may be implemented by adopting a Gibbs sampling method and the like; in S**305**, the obtaining, through calculation by the master calculation apparatus, the probability distribution between documents and topics and the probability distribution between topics and words according to the global count matrix of documents and topics and the global count matrix of topics and words may be implemented by adopting a Bayesian inference method and the like.

In the parameter inference method based on a Latent Dirichlet Allocation model according to the embodiment of the present invention, the number of topics, a first hyperparameter, and a second hyperparameter that maximize log likelihood functions of a probability distribution between documents and topics and a probability distribution between topics and words can be obtained through adaptively solving by using an expectation maximization algorithm, thereby avoiding the number of topics manually specified in advance according to experience and improving precision of a calculation result of a Latent Dirichlet Allocation model.

As shown in FIG. **4**, a parameter inference calculation apparatus **40** based on a Latent Dirichlet Allocation model according to the present invention includes: a Latent Dirichlet Allocation model calculation unit **401** configured to calculate a Latent Dirichlet Allocation model according to a preset initial first hyperparameter, a preset initial second hyperparameter, a preset initial number of topics, a preset initial global count matrix of documents and topics, and a preset initial global count matrix of topics and words, to obtain a probability distribution between documents and topics and a probability distribution between topics and words; a parameter estimation unit **402** configured to obtain, by using an expectation maximization algorithm, the number of topics, a first hyperparameter, and a second hyperparameter that maximize log likelihood functions of the probability distributions; and a determination and output unit **403** configured to determine whether the number of topics, the first hyperparameter, and the second hyperparameter converge, and if not, put the number of topics, the first hyperparameter, and the second hyperparameter into the Latent Dirichlet Allocation model for calculation until an optimal number of topics, an optimal first hyperparameter, and an optimal second hyperparameter that maximize the log likelihood functions of the probability distributions converge, and output the probability distributions, the optimal number of topics, the optimal first hyperparameter, and the optimal second hyperparameter that are eventually obtained.

In the parameter inference calculation apparatus based on a Latent Dirichlet Allocation model according to the embodiment of the present invention, the number of topics, a first hyperparameter, and a second hyperparameter that maximize log likelihood functions of a probability distribution between documents and topics and a probability distribution between topics and words can be obtained through adaptively solving by using an expectation maximization algorithm, thereby avoiding the number of topics manually specified in advance according to experience and improving precision of a calculation result of a Latent Dirichlet Allocation model.

As shown in FIG. **5**, a parameter inference calculation system based on a Latent Dirichlet Allocation model according to an embodiment of the present invention includes a master calculation apparatus **51** and a plurality of slave calculation apparatuses **52**, that is, a distributed parallel calculation system, and the master calculation apparatus **51** may be separately connected to the plurality of slave calculation apparatuses **52** in a distributed and parallel manner.

The master calculation apparatus **51** is configured to segment a document set into a plurality of document subsets; set an initial first hyperparameter, an initial second hyperparameter, an initial number of topics, an initial global count matrix of documents and topics, and an initial global count matrix of topics and words; send each document subset of a plurality of document subsets, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words to each slave calculation apparatus **52** of a plurality of slave calculation apparatuses **52** correspondingly; receive a local count matrix of documents and topics and a local count matrix of topics and words that are returned by each slave calculation apparatus **52**, and perform merging to obtain a global count matrix of documents and topics and a global count matrix of topics and words; determine whether a process of solving, by each slave calculation apparatus **52**, the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges; and if not, send the global count matrix of documents and topics and the global count matrix of topics and words to each slave calculation apparatus **52** correspondingly for calculation, and continue to update the local count matrix of documents and topics and the local count matrix of topics and words until the process of solving the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges, and output the global count matrix of documents and topics and global count matrix of topics and words that are eventually obtained; obtain, through calculation, a probability distribution between documents and topics and a probability distribution between topics and words according to the global count matrix of documents and topics and the global count matrix of topics and words; obtain, by using an expectation maximization algorithm, a first hyperparameter, a second hyperparameter, and the number of topics that maximize log likelihood functions of the probability distributions; determine whether the number of topics, the first hyperparameter, and the second hyperparameter converge, and if not, send the number of topics, the first hyperparameter, and the second hyperparameter to each slave calculation apparatus **52** until an optimal number of topics, an optimal first hyperparameter, and an optimal second hyperparameter that maximize the log likelihood functions of the probability distributions converge, and output the probability distributions, the optimal number of topics, the optimal first hyperparameter, and the optimal second hyperparameter that are eventually obtained.

The slave calculation apparatus **52** is configured to receive the document subset, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words that are sent by the master calculation apparatus **51**, calculate the Latent

Dirichlet Allocation model, update the local count matrix of documents and topics and the local count matrix of topics and words, and return the local count matrix of documents and topics and the local count matrix of topics and words to the master calculation apparatus **51**; receive the global count matrix of documents and topics, and the global count matrix of topics and words that are sent by the master calculation apparatus **51** and put them into the Latent Dirichlet Allocation model for local calculation and update the local count matrix of documents and topics and the local count matrix of topics and words; receive the number of topics, the first hyperparameter, and the second hyperparameter that are sent by the master calculation apparatus **51** and put them into the Latent Dirichlet Allocation model for local calculation and update the local count matrix of documents and topics and the local count matrix of topics and words.

In the parameter inference calculation system based on a Latent Dirichlet Allocation model according to the embodiment of the present invention, the number of topics, a first hyperparameter, and a second hyperparameter that maximize log likelihood functions of a probability distribution between documents and topics and a probability distribution between topics and words can be obtained through adaptively solving by using an expectation maximization algorithm, thereby avoiding the number of topics manually specified in advance according to experience and improving precision of a calculation result of a Latent Dirichlet Allocation model.

In addition, the parameter inference calculation system based on a Latent Dirichlet Allocation model according to the embodiment of the present invention adopts distributed and parallel calculation, thereby reducing calculation complexity on one machine and increasing a calculation speed.

Furthermore, as shown in FIG. **6**, the master calculation apparatus **51** includes: an initialization unit **511** configured to segment the document set into a plurality of document subsets; and set the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words; a parameter estimation unit **512** configured to construct the log likelihood functions of the probability distributions; receive the number of topics, the first hyperparameter, and the second hyperparameter which are sent by a Latent Dirichlet Allocation model calculation unit **513**, obtained by using the expectation maximization algorithm, and maximize the log likelihood functions of the probability distribution between documents and topics and the probability distribution between topics and words, determine whether the number of topics, the first hyperparameter, and the second hyperparameter converge; if not, send, through a first data transceiver unit **514**, the number of topics, the first hyperparameter, and the second hyperparameter to the slave calculation apparatus **52** until the optimal number of topics, the optimal first hyperparameter, and the optimal second hyperparameter that maximize the log likelihood functions of the probability distributions converge, and output the probability distributions, the optimal number of topics, the optimal first hyperparameter, and the optimal second hyperparameter that are eventually obtained; the Latent Dirichlet Allocation model calculation unit **513** configured to merge a plurality of local count matrixes of documents and topics and local count matrixes of topics and words that are received through the first data transceiver unit **514** to obtain the global count matrix of documents and topics and the global count matrix of topics and words; determine whether the process of solving, by each slave calculation apparatus **52**, the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges; and if not, send, through the first data transceiver unit **514**, the global count matrix of documents and topics and the global count matrix of topics and words to each slave calculation apparatus **52** correspondingly for calculation, and continue to update the local count matrix of documents and topics and the local count matrix of topics and words until the process of calculating the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges, and output the global count matrix of documents and topics and global count matrix of topics and words that are eventually obtained; and obtain, through calculation, the probability distribution between documents and topics and the probability distribution between topics and words according to the global count matrix of documents and topics and the global count matrix of topics and words, and send the probability distribution between documents and topics and the probability distribution between topics and words to the parameter estimation unit **512**; and the first data transceiver unit **514** configured to send each document subset of a plurality of document subsets, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words to each slave calculation apparatus **52** of a plurality of slave calculation apparatuses **52** correspondingly; receive the local count matrix of documents and topics and the local count matrix of topics and words that are returned by each slave calculation apparatus **52**, send the global count matrix of documents and topics and the global count matrix of topics and words to each slave calculation apparatus **52**; and send the number of topics, the first hyperparameter, and the second hyperparameter that are sent by the parameter estimation unit **512** to each slave calculation apparatus **52**.

The slave calculation apparatus **52** includes: a second data transceiver unit **521** configured to receive the document subset, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words that are sent by the master calculation apparatus **51**; send the global count matrix of documents and topics and the global count matrix of topics and words to the master calculation apparatus **51**; and receive the number of topics, the first hyperparameter, and the second hyperparameter that are sent by the master calculation apparatus **51**; and a Latent Dirichlet Allocation Allocation local calculation unit **522** configured to calculate the Latent Dirichlet Allocation model and perform update to obtain the local count matrix of documents and topics and the local count matrix of topics and words according to the document subset, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words that are received through the second data transceiver unit **521**; put the global count matrix of documents and topics and the global count matrix of topics and words that are received through the second data transceiver unit **521** into the Latent Dirichlet Allocation model for local calculation and update the local count matrix of documents and topics and the local count matrix of topics and words; and put the number of topics, the first hyperparameter, and the second hyperparameter that are received through the second data transceiver unit **521** into the Latent Dirichlet Allocation model for local calculation and update the local count matrix of documents and topics and the local count matrix of topics and words.

FIG. **6** shows a parameter inference calculation system based on a Latent Dirichlet Allocation model according to another embodiment of the present invention. A master calculation apparatus **51** includes an initialization unit **511**, a parameter estimation unit **512**, a Latent Dirichlet Allocation calculation unit **513**, and a first data transceiver unit **514**. A slave calculation apparatus **52** includes a second data transceiver unit **521** and a Latent Dirichlet Allocation local calculation unit **522**.

Main functions of the initialization unit **511** include document segmentation and parameter initialization. In an initialization phase, the initialization unit **511** segments a document set including M documents into P subsets and establishes an index for each subset. To perform iteration, an initial global count matrix of documents and topics C^{doc} and an initial global count matrix of topics and words C^{word} are given, and meanwhile, an initial value is set for each parameter of a Latent Dirichlet Allocation model: $\alpha=\alpha_0$, $\beta=\beta_0$, and $K=K_0$, where α and β are hyperparameters, and K is the number of topics.

The parameter estimation unit **512** is configured to establish a likelihood function, maximize the likelihood function, and update a parameter of the Latent Dirichlet Allocation model. Based on the Latent Dirichlet Allocation model, the parameter estimation unit **512** obtains, through the Latent Dirichlet Allocation calculation unit **513**, a probability distribution p(Z|d) between documents and topics and a probability distribution p(W|Z) between topics and words, and establishes, according to the Bayesian Theory, a target likelihood function:

$$L(\alpha, \beta, K) = \sum_{d=1}^{M} \log p(w_d \mid \alpha, \beta, K).$$

By maximizing the target likelihood function $L(\alpha, \beta, K)$ model parameters $\alpha^{(n)}$, $\beta^{(n)}$, $K^{(n)}$ corresponding to this iteration are obtained, and it is determined whether iteration of parameter estimation is ended; if the iteration is not ended, the model parameters $\alpha=\alpha^{(n)}$, $\beta=\beta^{(n)}$ and $K=K^{(n)}$ are updated, and the updated model parameters are sent to each slave calculation apparatus **52** through the first data transceiver unit **514**.

The Latent Dirichlet Allocation calculation unit **513** receives a local count matrix C_{lp}^{doc} of documents and topics and a local count matrix C_{lp}^{word} of topics and words that are obtained through calculation by each slave calculation apparatus **52** and forwarded by the first data transceiver unit **514**, and performs merging to obtain the global count matrix C^{doc} of documents and topics and the global count matrix C^{word} of topics and words. The Latent Dirichlet Allocation calculation unit **513** determines whether a process of solving, by each slave calculation apparatus **52**, the Latent Dirichlet Allocation model and updating the local count matrix C_{lp}^{doc} of documents and topics and the local count matrix C_{lp}^{word} of topics and words converges; and if not, sends the global count matrix C^{doc} of documents and topics and the global count matrix C^{word} of topics and words to each slave calculation apparatus **52** through the first data transceiver unit **514** correspondingly, continues to update the local count matrix C_{lp}^{doc} of documents and topics and the local count matrix C_{lp}^{word} of topics and words until the process of solving the Latent Dirichlet Allocation model and updating the local count matrix C_{lp}^{doc} of documents and topics and the local count matrix C_{lp}^{word} of topics and words converges; obtains, through calculation, the probability distribution p(Z|d) of documents and topics and the probability distribution p(W|Z) of topics and words according to the global count matrix C_{doc} of documents and topics and the global count matrix C^{word} of topics and words, and sends the probability distributions p(Z|d) and p(W|Z) and corresponding parameters K, α and β to the parameter estimation unit **512**.

In the initialization stage, the first data transceiver unit **514** sends each document subset D^p, the initialization parameters $\alpha=\alpha_0$, $\beta=\beta_0$ and $K=K_0$, the given initial global count matrix C^{doc} of documents and topics and the initial global count matrix of topics and words to the corresponding slave calculation apparatus **52**. In the parameter estimation stage, the first data transceiver unit **514** receives the global count matrix of documents and topics and the global count matrix of topics and words that are returned by each slave calculation apparatus **52** and sends them to each slave calculation apparatus **52**, forwards them to the Latent Dirichlet Allocation calculation unit **513**; sends the global count matrix C^{doc} of documents and topics and the global count matrix C^{word} of topics and words to each slave calculation apparatus **52**; sends parameters α', β', K' updated by the parameter estimation unit **512** to each slave calculation apparatus **52**.

A Latent Dirichlet Allocation local calculation unit **522** of the slave calculation apparatus **52**, according to the Latent Dirichlet Allocation model parameters K, a and **13** and document data sent by the master calculation apparatus **51**, samples a document subset corresponding to this calculation apparatus, assigns a new topic for each word in each document, updates C_{lp}^{word} and C_{lp}^{doc}, (C_{lp}^{word} and C_{lp}^{doc} represent the count matrix of topics and words and the count matrix of documents and topics on each slave calculation apparatus **52** respectively), and sends, through the second data transceiver unit **521**, the updated local count matrix C_{lp}^{word} of topics and words and the updated local count matrix C_{lp}^{doc} of documents and topics to the master calculation apparatus **51**.

In the initialization stage, the second data transceiver unit **521** receives the corresponding document subset D^p, the initialization parameters $\alpha=\alpha_0$, $\beta=\beta_0$ and $K=K_0$, and the initial global count matrix C^{doc} of documents and topics, and the initial global count matrix C^{word} of topics and words that are sent by the master calculation apparatus **51**. In the parameter estimation stage, the second data transceiver unit **521** receives model parameters α', β', K' updated through maximization likelihood estimation; receives the global count matrix C^{doc} of documents and topics and the global count matrix C^{word} of topics and words that are sent by the master calculation apparatus, and sends the local count matrix C_{lp}^{word} of topics and words and the local count matrix C_{lp}^{doc} of documents and topics that are obtained through calculation by the Latent Dirichlet Allocation local calculation unit **522** to the master calculation apparatus **51**.

Main methods for solving the Latent Dirichlet Allocation model usually include a Gibbs sampling-based algorithm, a variational expectation maximum (variational EM) based algorithm, and an expectation-propagation algorithm. In the embodiment of the present invention, it is assumed that the Gibbs sampling solving algorithm is adopted, it is not limited to the Gibbs sampling algorithm.

A unit of the apparatus according to the embodiment of the present invention may be a processor, an application specific circuit, and the like.

In the parameter inference calculation system based on a Latent Dirichlet Allocation model according to the embodiment of the present invention, the number of topics, a first hyperparameter, and a second hyperparameter that maximize log likelihood functions of a probability distribution between

documents and topics and a probability distribution between topics and words can be obtained through adaptively solving by using an expectation maximization algorithm, thereby avoiding the number of topics manually specified in advance according to experience and improving precision of a calculation result of a Latent Dirichlet Allocation model.

In addition, the parameter inference calculation system based on a Latent Dirichlet Allocation model according to the embodiment of the present invention adopts distributed and parallel calculation, thereby reducing calculation complexity on one machine and increasing a calculation speed.

The foregoing description is merely specific embodiments of the present invention, but is not intended to limit the protection scope of the present invention. Any variation or replacement readily figured out by persons skilled in the art within the technical scope disclosed in the present invention shall fall within the protection scope of the present invention. Therefore, the protection scope of the present invention shall be subject to the protection scope of the claims.

What is claimed is:

1. A parameter inference method based on a Latent Dirichlet Allocation model, comprising:

calculating the Latent Dirichlet Allocation model according to a preset initial first hyperparameter, a preset initial second hyperparameter, a preset initial number of topics a preset initial global count matrix of documents and topics, and a preset initial global count matrix of topics and words, to obtain a probability distribution between documents and topics and a probability distribution between topics and words;

obtaining, by using an expectation maximization algorithm, a first hyperparameter, a second hyperparameter, and the number of topics that maximize log likelihood functions of the probability distributions; and

determining whether the first hyperparameter, the second hyperparameter, and the number of topics converge, and when the first hyperparameter and the second hyperparameter do not converge, putting the first hyperparameter, the second hyperparameter, and the number of topics into the Latent Dirichlet Allocation model for calculation until an optimal first hyperparameter, an optimal second hyperparameter, and an optimal number of topics that maximize the log likelihood functions of the probability distributions converge, and outputting the probability distributions, the optimal first hyperparameter, the optimal second hyperparameter, and the optimal number of topics that are eventually obtained,

wherein calculating the Latent Dirichlet Allocation model according to the preset initial first hyperparameter, the preset initial second hyperparameter, the preset initial number of topics, the preset initial global count matrix of documents and topics, and the preset initial global count matrix of topics and words, to obtain the probability distribution between documents and topics and the probability distribution between topics and words comprises:

segmenting, by a master calculation apparatus, a document set into a plurality of document subsets, and setting the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the preset initial global count matrix of documents and topics, and the preset initial global count matrix of topics and words;

sending, by the master calculation apparatus, each document subset of the plurality of document subsets, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the preset initial global count matrix of documents and topics, and the preset initial global count matrix of topics and words to each slave calculation apparatus of a plurality of slave calculation apparatuses correspondingly such that each slave calculation apparatus of the plurality of slave calculation apparatuses solves the Latent Dirichlet Allocation model and updates a local count matrix of documents and topics and a local count matrix of topics and words according to a received preset initial global count matrix of documents and topics, a received initial global count matrix of topics and words, the received initial first hyperparameter, the received initial second hyperparameter, and the received initial number of topics;

receiving, by the master calculation apparatus, the local count matrix of documents and topics and the local count matrix of topics and words that are returned by each slave calculation apparatus, and performing merging to obtain a global count matrix of documents and topics and a global count matrix of topics and words;

determining, by the master calculation apparatus, whether a process of solving, by each slave calculation apparatus, the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges, and when the process of solving the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words does not converge, sending the global count matrix of documents and topics and the global count matrix of topics and words to each slave calculation apparatus correspondingly for calculation, and continuing to update the local count matrix of documents and topics and the local count matrix of topics and words until the process of solving the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges, and outputting the global count matrix of documents and topics and the global count matrix of topics and words that are eventually obtained; and

calculating, by the master calculation apparatus, the probability distribution between documents and topics and the probability distribution between topics and words according to the global count matrix of documents and topics and the global count matrix of topics and words.

2. The method according to claim **1**, wherein determining whether the first hyperparameter, the second hyperparameter, and the number of topics converge, and when the first hyperparameter, the second hyperparameter, and the number of topics do not converge, putting the first hyperparameter, the second hyperparameter, and the number of topics into the Latent Dirichlet Allocation model for calculation comprises determining, by the master calculation apparatus, whether the first hyperparameter, the second hyperparameter, and the number of topics converge, and when the first hyperparameter, the second hyperparameter, and the number of topics do not converge, sending the first hyperparameter, the second hyperparameter, and the number of topics to each slave calculation apparatus such that each slave calculation apparatus puts the first hyperparameter, the second hyperparameter, and the number of topics into the Latent Dirichlet Allocation model for local calculation.

3. A parameter inference calculation apparatus based on a Latent Dirichlet Allocation model, comprising:

a receiver;

a plurality of processors; and

a memory unit implemented by hardware,

wherein the plurality of processors comprise a master processor and one or more slave processors,

wherein the receiver is configured to receive a document set,

wherein the master processor is configured to:

segment the document set into a plurality of document subsets;

set an initial first hyperparameter, an initial second hyperparameter, the initial number of topics, an initial global count matrix of documents and topics, and an initial global count matrix of topics and words;

send to each slave processor a document subset, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words;

receive from each slave processor a local count matrix of documents and topics and a local count matrix of topics and words, and perform merging to obtain a global count matrix of documents and topics and a global count matrix of topics and words;

determine, for each slave processor, whether the slave processor solves the Latent Dirichlet Allocation model and updates the local count matrix of documents and topics and the local count matrix of topics and words converges, and when the process of solving the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words does not converge, send the global count matrix of documents and topics and the global count matrix of topics and words to the slave processor for calculation, and continue to update the local count matrix of documents and topics and the local count matrix of topics and words until the process of calculating the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges, and output the global count matrix of documents and topics and global count matrix of topics and words that are eventually obtained;

obtain, through calculation, a probability distribution between documents and topics and a probability distribution between topics and words according to the global count matrix of documents and topics and the global count matrix of topics and words;

obtain, by using an expectation maximization algorithm, a first hyperparameter, a second hyperparameter, and the number of topics that maximize log likelihood functions of the probability distributions;

determine, for each slave processor, whether the first hyperparameter, the second hyperparameter, and the number of topics converge, and when the first hyperparameter, the second hyperparameter, and the number of topics do not converge, send the first hyperparameter, the second hyperparameter, and the number of topics to the slave processor until an optimal first hyperparameter, an optimal second hyperparameter, and the optimal number of topics that maximize the log likelihood functions of the probability distributions converge, and output the probability distributions, the optimal first hyperparameter, the optimal second hyperparameter, and the optimal number of topics that are eventually obtained, and

wherein each slave processor is configured to:

receive the document subset, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words that are sent by the master processor, calculate the Latent Dirichlet Allocation model, update the local count matrix of documents and topics and the local count matrix of topics and words, and return the local count matrix of documents and topics and the local count matrix of topics and words to the master processor;

receive the global count matrix of documents and topics, the global count matrix of topics and words, the first hyperparameter, the second hyperparameter, and the number of topics that are sent by the master processor and put them into the Latent Dirichlet Allocation model for local calculation, and

wherein the memory unit is configured to store the document set, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, the initial global count matrix of topics and words, the local count matrices of documents and topics, the local count matrices of topics and words, the global count matrix of documents and topics, and the global count matrix of topics and words.

4. The calculation apparatus according to claim 3, wherein the master processor comprises:

an initialization unit configured to:

segment the document set into the plurality of document subsets; and

set the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words;

a parameter estimation unit configured to:

construct the log likelihood functions of the probability distributions;

obtain, by using the expectation maximization algorithm, the first hyperparameter, the second hyperparameter, and the number of topics that maximize the log likelihood functions of the probability distributions;

determine whether the first hyperparameter, the second hyperparameter, and the number of topics converge, and when the first hyperparameter, the second hyperparameter, and the number of topics do not converge, send, through a first data transceiver unit, the first hyperparameter, the second hyperparameter, and the number of topics to the slave processor calculation apparatus, until the optimal first hyperparameter, the optimal second hyperparameter, and the optimal number of topics that maximize the log likelihood functions of the probability distributions converge, and output the probability distributions, the optimal first hyperparameter, the optimal second hyperparameter, and the optimal number of topics that are eventually obtained;

a Latent Dirichlet Allocation model calculation unit configured to:

merge a plurality of local count matrixes of documents and topics and local count matrixes of topics and words that are received through the first data trans-

ceiver unit to obtain the global count matrix of documents and topics and the global count matrix of topics and words;

determine whether a process of solving, by each slave processor, the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges, and when the process of solving the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words does not converge, send the global count matrix of documents and topics and the global count matrix of topics and words to each slave processor for calculation, and continue to update the local count matrix of documents and topics and the local count matrix of topics and words until the process of calculating the Latent Dirichlet Allocation model and updating the local count matrix of documents and topics and the local count matrix of topics and words converges, and output the global count matrix of documents and topics and global count matrix of topics and words that are eventually obtained; and

obtain, through calculation, the probability distribution between documents and topics and the probability distribution between topics and words according to the global count matrix of documents and topics and the global count matrix of topics and words; and

the first data transceiver unit configured to:

send each document subset of a plurality of document subsets, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words to each slave processor correspondingly;

receive the local count matrix of documents and topics and the local count matrix of topics and words that are returned by each slave processor;

send the global count matrix of documents and topics and the global count matrix of topics and words to each slave processor; and

send the first hyperparameter, the second hyperparameter, and the number of topics to each slave processor.

5. The calculation system apparatus according to claim **4**, wherein the slave processor comprises:

a second data transceiver unit configured to:

receive the document subset, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words that are sent by the master processor;

send the local count matrix of documents and topics and the local count matrix of topics and words to the master processor;

receive the global count matrix of documents and topics and the global count matrix of topics and words that are sent by the master processor; and

receive the first hyperparameter, the second hyperparameter, and the number of topics that are sent by the master processor; and

a Latent Dirichlet Allocation model local calculation unit configured to:

calculate the Latent Dirichlet Allocation model and perform update to obtain the local count matrix of documents and topics and the local count matrix of topics and words according to the document subset, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words that are received through the second data transceiver unit;

put the global count matrix of documents and topics and the global count matrix of topics and words that are received through the second data transceiver unit into the Latent Dirichlet Allocation model for local calculation; and

put the first hyperparameter, the second hyperparameter, and the number of topics that are received through the second data transceiver unit into the Latent Dirichlet Allocation model for local calculation.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,213,943 B2
APPLICATION NO. : 14/153257
DATED : December 15, 2015
INVENTOR(S) : Kopylov Vladislav et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

IN THE CLAIMS

Column 18, Line 3, Claim 5 should read:

The calculation apparatus according to claim 4, wherein the slave processor comprises:

a second data transceiver unit configured to:

receive the document subset, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words that are sent by the master processor;

send the local count matrix of documents and topics and the local count matrix of topics and words to the master processor;

receive the global count matrix of documents and topics and the global count matrix of topics and words that are sent by the master processor; and

receive the first hyperparameter, the second hyperparameter, and the number of topics that are sent by the master processor; and

a Latent Dirichlet Allocation model local calculation unit configured to:

calculate the Latent Dirichlet Allocation model and perform update to obtain the local count matrix of documents and topics and the local count matrix of topics and words according to the document subset, the initial first hyperparameter, the initial second hyperparameter, the initial number of topics, the initial global count matrix of documents and topics, and the initial global count matrix of topics and words that are received through the second data transceiver unit;

put the global count matrix of documents and topics and the global count matrix of topics and words that are received through the second data transceiver unit into the Latent Dirichlet Allocation model for local calculation; and

put the first hyperparameter, the second hyperparameter, and the number of topics that are received through the second data transceiver unit into the Latent Dirichlet Allocation model for local calculation.

Signed and Sealed this
Twelfth Day of April, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office